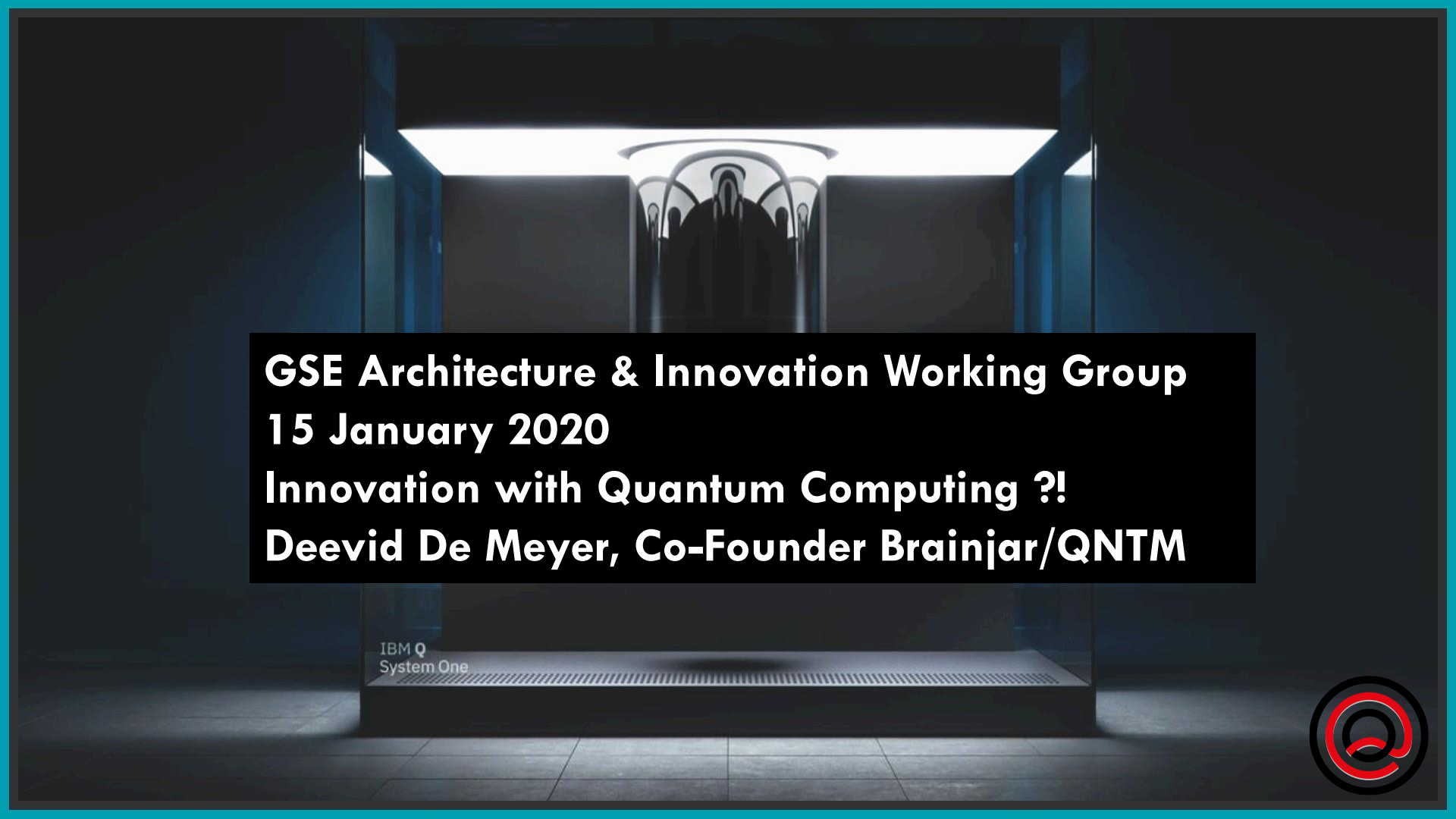


GSE Architecture & Innovation Working Group
15 January 2020
Innovation with Quantum Computing ?!

Deevid De Meyer, Co-Founder Brainjar/QNTM

QNTM

Quantum Computing

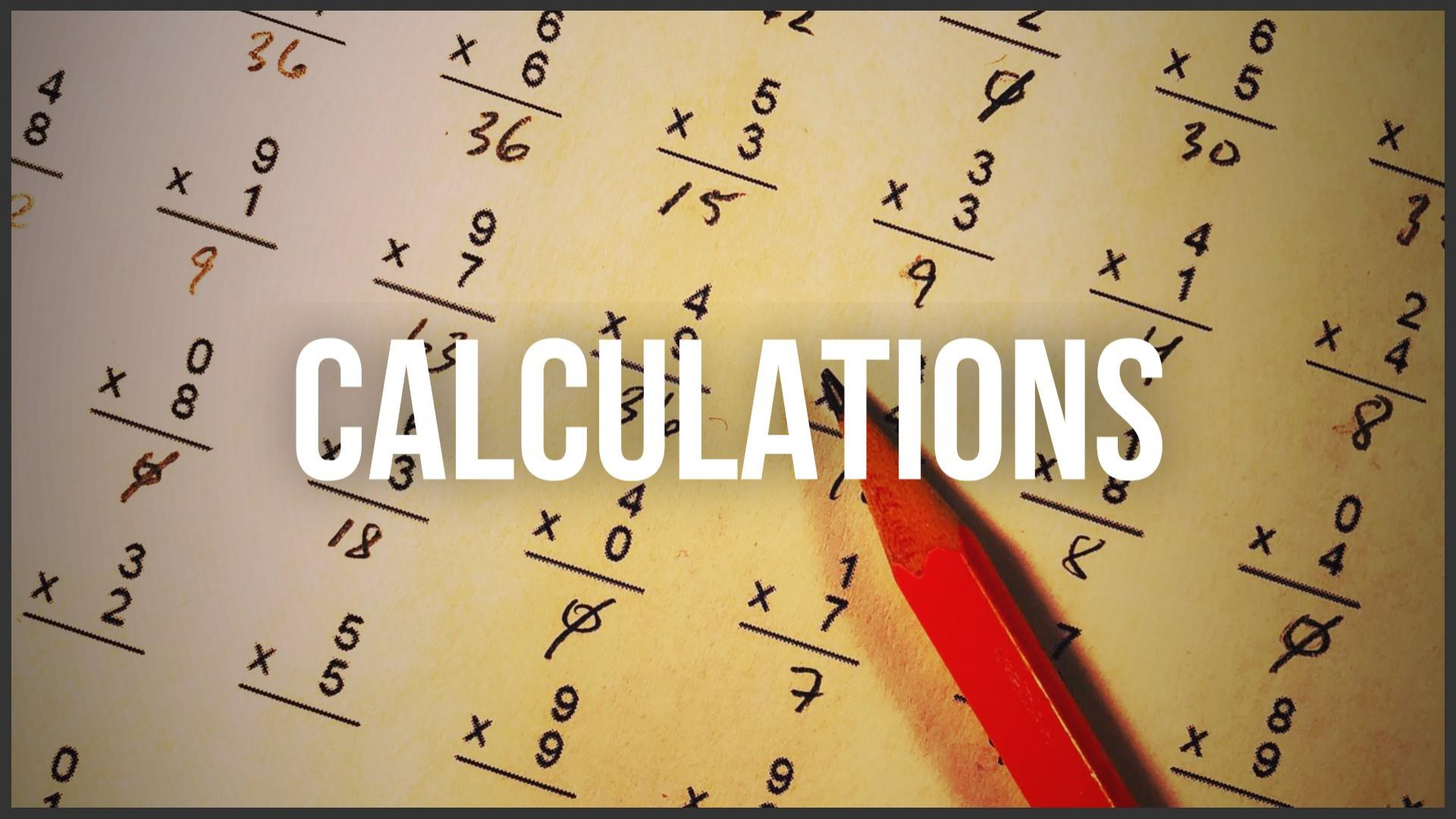
present
and beyond
Quantum computers
FIFTH GENERATION

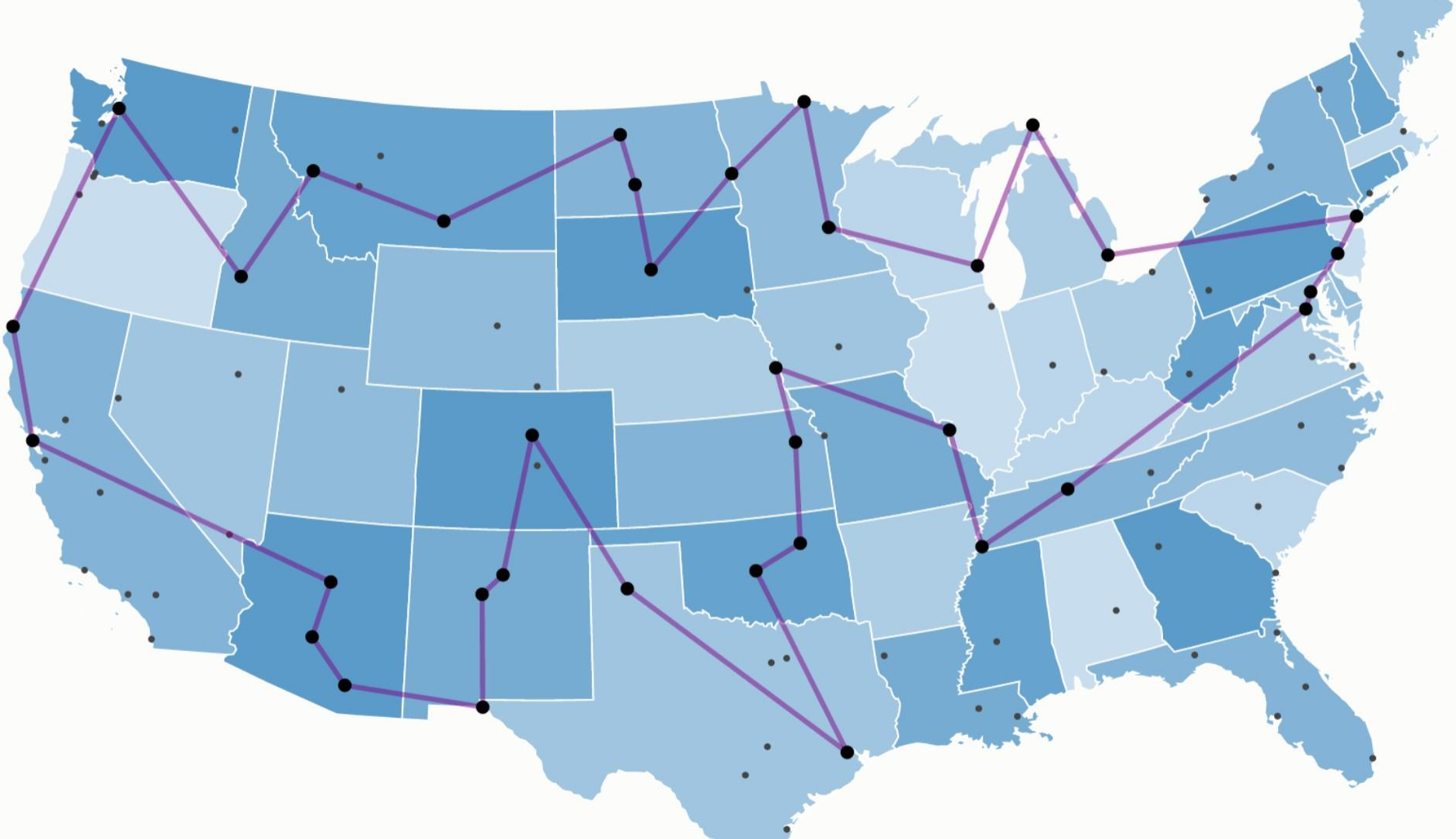
1971–present
Microprocessors
FOURTH GENERATION

1964-1971
Integrated circuits
THIRD GENERATION

1956-1964
Transistors
SECOND GENERATION

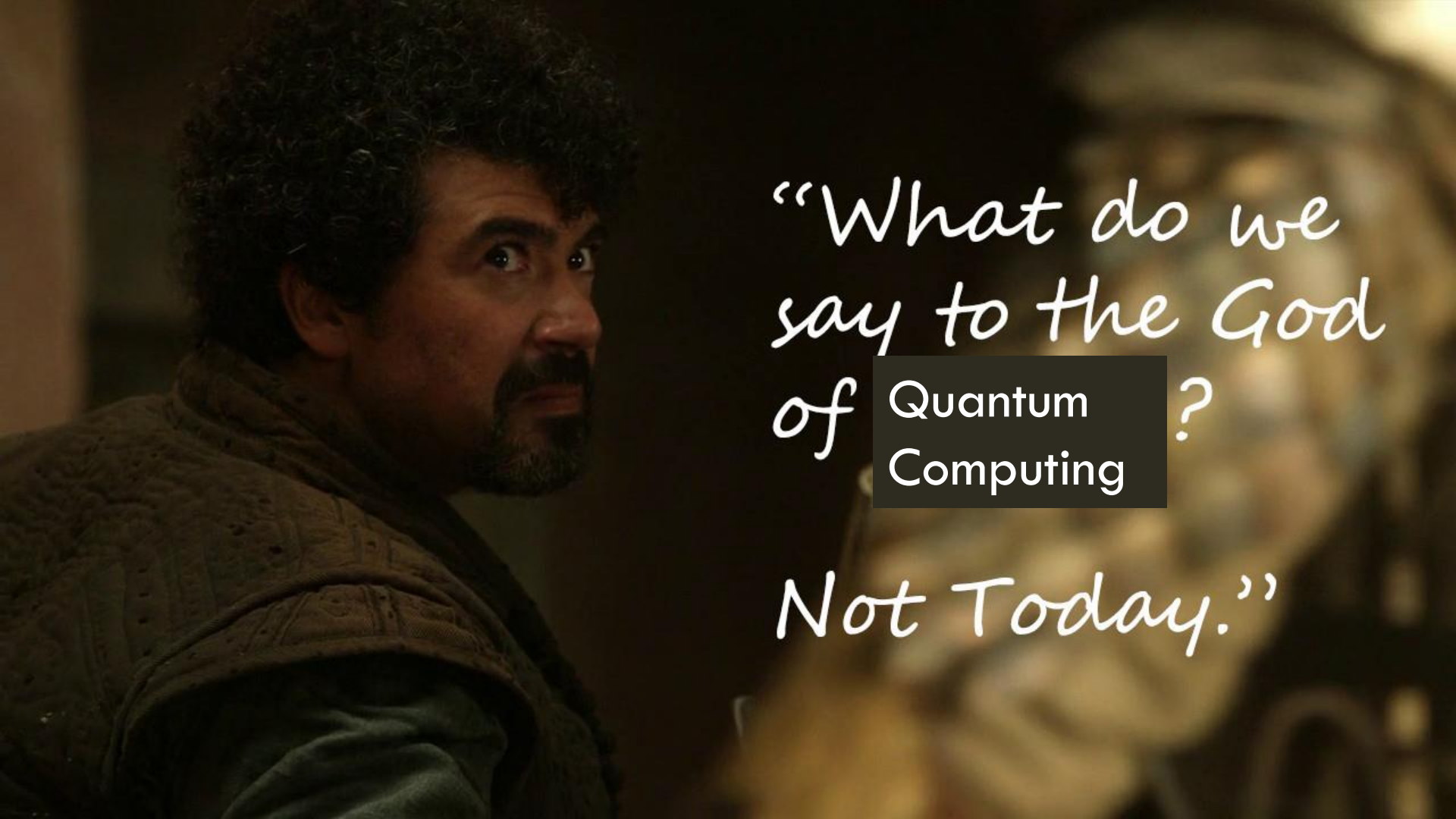
1940-1956
Vacuum tubes
FIRST GENERATION


CALCULATIONS



TRAVELLING SALESMAN PROBLEM

Number of cities	Combinations	Time Taken
1	1	.5 ns
2	2	1 ns
3	6	3 ns
4	24	12 ns
5	120	.6 µs
10	3,628,800	2 ms
20	2.43 e18	38 years
30	**4.42 e30**	**7.00 e+13 years (6 AoU's)**

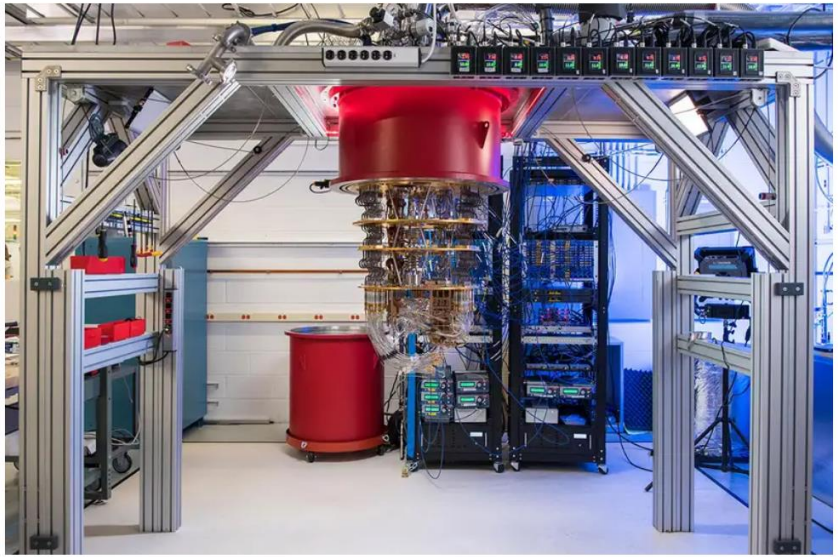

"What do we say to the God of Quantum Computing ?
Not Today."

QUANTUM SUPREMACY IS HERE! (OR NOT?)

It’s official: Google has achieved quantum supremacy

PHYSICS 23 October 2019

By Daniel Cossins



Google’s quantum computer is a record-breaker
HANNAH BENET/Google

ABSTRACTIONS BLOG

Google and IBM Clash Over Milestone Quantum Computing Experiment

21

Today Google announced that it achieved "quantum supremacy." Its chief quantum computing rival, IBM, said it hasn't. The disagreement hinges on what the term really means.

SCOTT AARONSON

Shor, I'll do it

SO WAS IT ALL JUST EMPTY HYPE?

No. As I put it the other day, it's not an everythingburger, but it's certainly at least a somethingburger!

It's like, have a little respect for the immensity of what we're talking about here, and for the terrifying engineering that's needed to make it reality. Before quantum supremacy, by definition, the QC skeptics can all laugh to each other that, for all the billions of dollars spent over 20+ years, *still* no quantum computer has even once been used to solve any problem faster than your laptop could solve it. In a post-quantum-supremacy world, that's no longer the case. A superposition involving 2^{50} or 2^{60} complex numbers has been computationally harnessed, using time and space resources that are minuscule compared to 2^{50} or 2^{60}.

I keep bringing up the Wright Flyer (…). It's like, **if you believed that useful air travel was fundamentally impossible, then seeing a dinky wooden propeller plane keep itself aloft wouldn't refute your belief … *but it sure as hell shouldn't reassure you either*.**

SO DOES IT HAVE ANY USE?

When people were first thinking about this subject, it seemed pretty obvious that the answer was “no”! (I know because I was one of the people.)

Recently, however, the situation has changed. For example, because of my certified randomness protocol, which shows how a sampling-based quantum supremacy experiment could almost immediately be repurposed to generate bits that can be *proven to be random* to a skeptical third party (under computational assumptions). **This, in turn, has possible applications to proof-of-stake cryptocurrencies and other cryptographic protocols**. I’m hopeful that more such applications will be discovered in the near future.

SO WHAT DO WE NEED?

SO WHAT DO WE NEED?

How the quest for a scalable quantum computer is helping fight cancer

Microsoft wants to revolutionize MRIs with quantum-inspired algorithms and HoloLens

Microsoft will help optimize the pulse sequences by mapping the problem to a form suitable for quantum computers and then use a quantum-inspired algorithm, which runs on the classical computers we have today.

Quantum Computing
Use Cases

OPTIMISATION

TRAFFIC MANAGEMENT - VW

Volkswagen is launching in Lisbon the world's first pilot project for traffic optimization using a quantum computer. This system uses a **D-Wave** quantum computer and calculates the fastest route for each of the nine participating buses individually and almost in real-time.

The Volkswagen traffic management system includes two components – **passenger number prediction** and **route optimization** by quantum computing. For predictions, the development team from Volkswagen is using data analytics tools to identify stops with especially high passenger numbers at certain times. For this purpose, anonymized geo-coordinates and passenger flow data are used. The objective is to offer as many people as possible tailor-made transport possibilities and to ensure optimum utilization of the bus fleet.

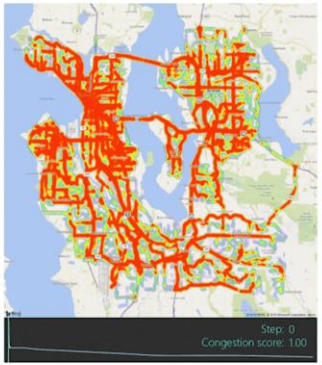
For the pilot project in Lisbon, **26 stops** were selected and connected to form four bus links. For example, one of these runs from the WebSummit conference facility to the Marqués de Pombal traffic node in the city center.

TRAFFIC MANAGEMENT - FORD

A scenario involving as many as 5,000 vehicles, each with 10 different route choices available to them — simultaneously requesting routes across Metro Seattle.

In 20 seconds, balanced routing suggestions were delivered to the vehicles that resulted in a 73 percent improvement in total congestion when compared to “selfish” routing. The average commuting time, meanwhile, was also reduced by 8 percent — an annual reduction of more than 55,000 hours saved in congestion across this simulated fleet.

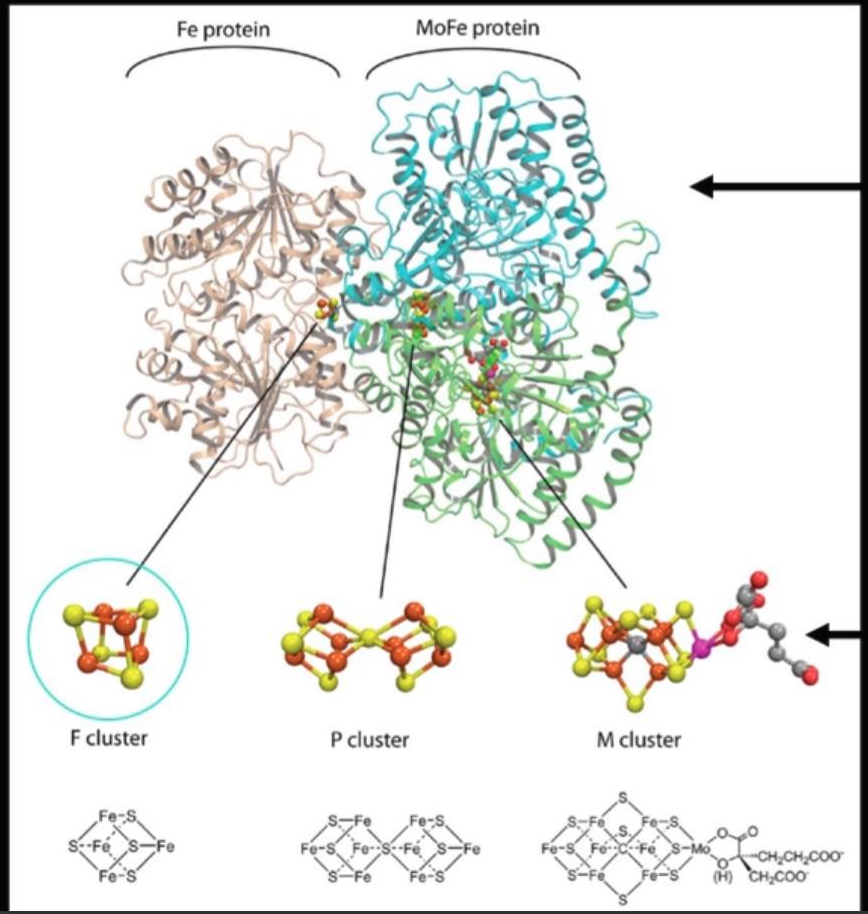
https://medium.com/@ford/why-ford-is-taking-a-quantum-leap-into-the-future-of-computing-453128a2ea9f



Quantum Computing
Use Cases

CHEMISTRY

Chemistry



Nitrogenase enzyme involved in N_2 to NH_4 reaction

These regions are involved in different reaction stages

Iron sulfide clusters (Fe_xS_y) of different sizes.

Simulating this cluster is at the limit of classical computers

Chem. Rev., **2014**, *114* (8), pp 4041–4062
DOI: 10.1021/cr400641x

MATERIALS

By weight, spider silk is stronger than steel and is made at body temperature rather than forged in a furnace. The only problem is that it is produced by an organic reaction which is impossible for our computers to simulate. Quantum computing could help us understand how to produce spider silk efficiently, and much more:

- Materials with more advantageous strength-toweight ratios
- Batteries that offer significantly higher energy densities
- More efficient synthetic and catalytic processes that could help with energy generation and carbon capture.

HEALTHCARE

Quantum computers could help speed up the process of comparing the interactions and effects of different drugs on a range of diseases to determine the best medications.

Additionally, quantum computing could also lead to truly **personalized medicine,** using advancements in genomics to create tailored treatment plans specific to every patient.

Genome sequencing creates lots of data such that a representation of a person's whole DNA strand requires massive computational power and storage capacity. Companies are rapidly bringing down the cost and resources needed to sequence the human genome; however, a quantum computer would theoretically make the way genomes are sequenced more efficient and easier to scale globally.

FINANCE

Specifically, the areas of quantum computing that show the most promise for financial services are in solving complex optimization problems such as **portfolio risk optimization and fraud detection.**

Quantum computing could be used to better determine attractive portfolios given thousands of assets with interconnecting dependencies and identify key fraud patterns more effectively.

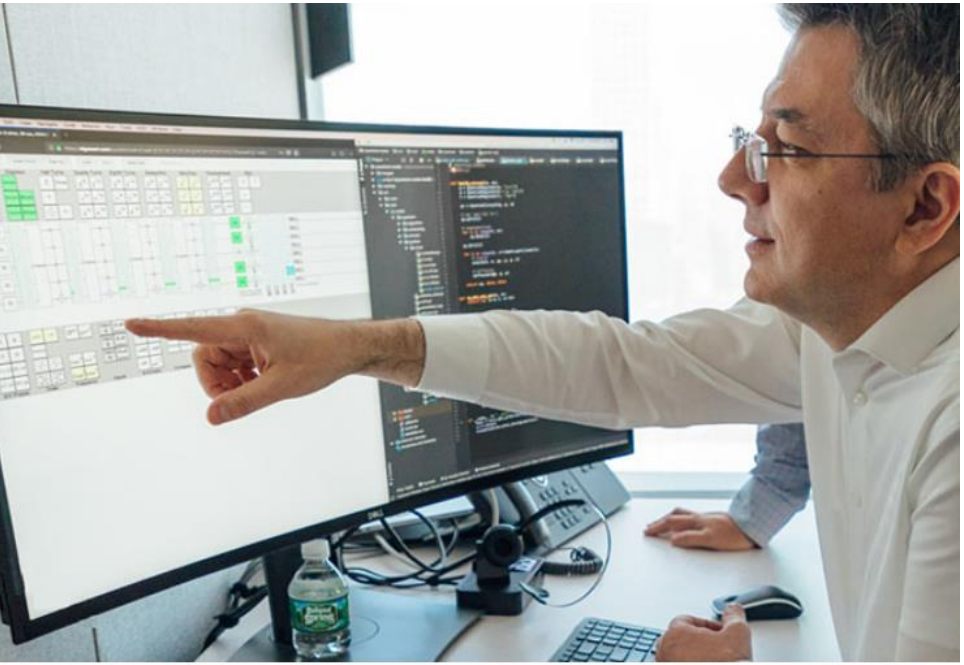
Option Pricing using Quantum Computers

Nikitas Stamatopoulos,[1] Daniel J. Egger,[2] Yue Sun,[1] Christa Zoufal,[2,3] Raban Iten,[2] Ning Shen,[1] and Stefan Woerner[2]

[1] *J.P. Morgan Chase Quantitative Research, New York, NY, 10017*
[2] *IBM Research – Zurich*
[3] *ETH Zurich*

(Dated: July 5, 2019)

We present a methodology to price options and portfolios of options on a gate-based quantum computer using amplitude estimation, an algorithm which provides a quadratic speedup compared to classical Monte Carlo methods. The options that we cover include vanilla options, multi-asset options and path-dependent options such as barrier options. We put an emphasis on the implementation of the quantum circuits required to build the input states and operators needed by amplitude estimation to price the different option types. Additionally, we show simulation results to highlight how the circuits that we implement price the different option contracts. Finally, we examine the performance of option pricing circuits on quantum hardware using the IBM Q Tokyo quantum device. We employ a simple, yet effective, error mitigation scheme that allows us to significantly reduce the errors arising from noisy two-qubit gates.



JPMorgan Chase Prepares for FinTech's Quantum Leap

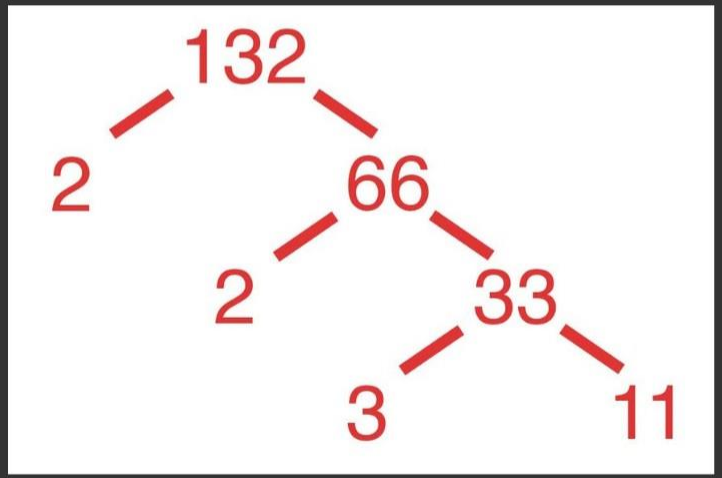
The Starting Line

JPMorgan Chase wants to be ready for the quantum leap. With that in mind, the company has tasked senior engineer Constantin Gonciulea with building a "**quantum culture**."

Gonciulea is the unofficial leader of the company's foray into discovering how quantum computing can change the financial industry.

Every two weeks he gathers a select group of 25 computer scientists to pour through the latest research and breakthroughs in quantum computing.

PRIME FACTORIZATION - BASIS OF MODERN ENCRYPTION



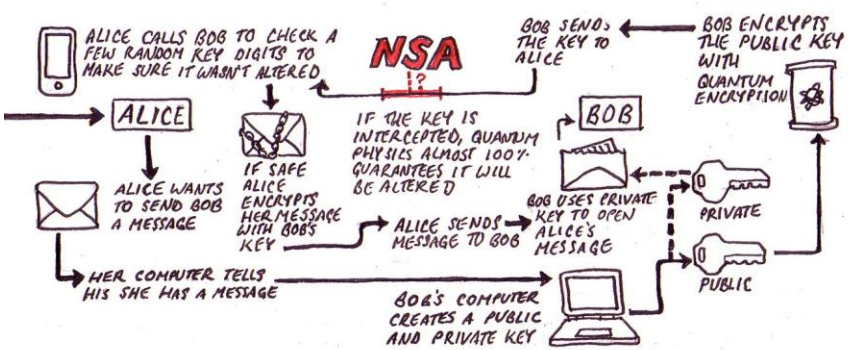
- ANY NUMBER CAN BE WRITTEN AS A PRODUCT OF PRIME NUMBERS
- ASSUME Z = X * Y
- CHECKING IF X * Y = Z IS EASY
- FINDING X AND Y FROM Z IS HARD

ENCRYPTION

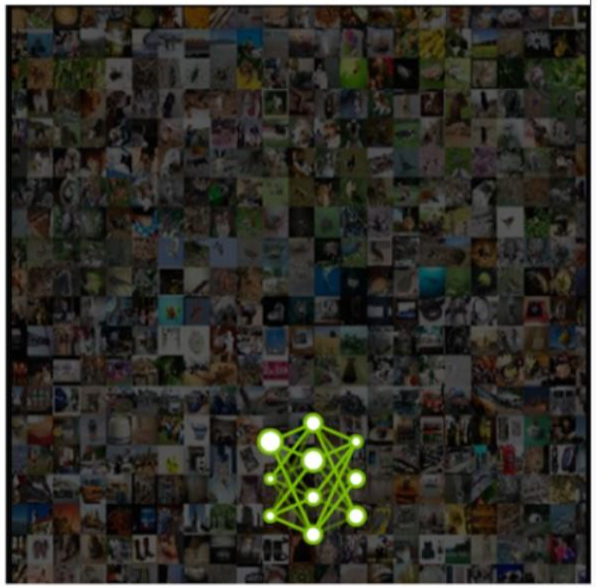
Quantum computers can be used to break cryptographic codes that we use today to keep sensitive data and electronic communications secure.

However, quantum computers could also be used to secure data from quantum hacking — a technique known as **quantum encryption.**

The most important point is that if quantum encrypted communications are intercepted by anyone, the encryption scheme will show immediate signs of disruption and reveal that the correspondence is not secure. This relies on the principle that the **act of measuring a quantum system disrupts the system.** This is known as the **"measurement effect."**

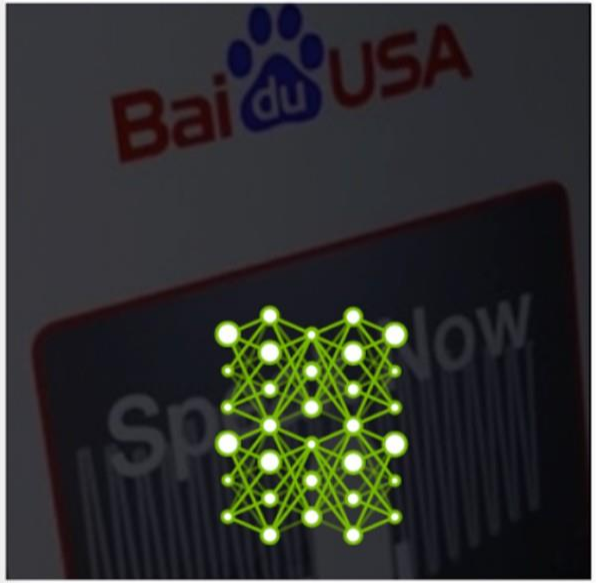


7 ExaFLOPS
60 Million Parameters



2015 - Microsoft ResNet
Superhuman Image Recognition

20 ExaFLOPS
300 Million Parameters

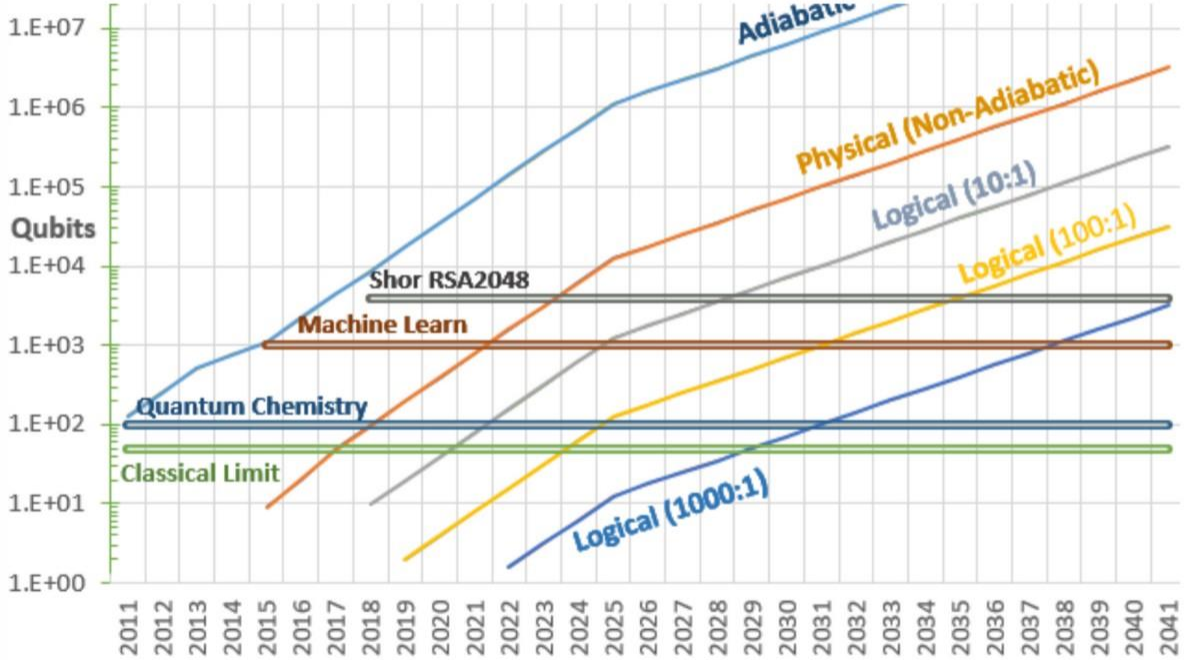


2016 - Baidu Deep Speech 2
Superhuman Voice Recognition

100 ExaFLOPS
8700 Million Parameters

2017 - Google Neural Machine Translation
Near Human Language Translation

Applying Moore's Law to Quantum Qubits



Today's State-of-the-Art Qubit Count

Company	Type - Tech	Now	Next Goal
Intel	Gate - Superconducting	17	49
Google	Gate - Superconducting	22	49
IBM	Gate - Superconducting	16	TBD
Rigetti	Gate - Superconducting	8	TBD
IonQ	Gate - Ion Trap	7	20-50
SQC Pty	Gate - Spin	N/A	10
Harvard/MIT	Qtm Simulator - Ion Trap	51	TBD
D-Wave	Anneal - Superconducting	2048	4096
iARPA QEO	Anneal - Superconducting	N/A	100

SO WHY NOW?

- Though quantum hardware hasn't reached maturity, software is already being written
- Many platforms focus on hardware independence, ensuring future compatibility of quantum software
- Due to high cost and complexity of quantum hardware, limited capacity will be available initially
- Building quantum experience will shield you from snake oil salesmen

Protein folding and drug discovery: Simulated annealing is an algorithm currently used for the prediction of the effects of potential therapeutic approaches while optimizing for non-adverse effects. Quantum computing can replace some of these techniques, and may be able to show improvements at scale in the next few years such as advancing drug design to the point of providing personalized prescription drugs for individual patients.

Supply chain and purchasing: Supply chain optimization problems come in many different forms, such as procurement, production and distribution. As quantum computing improves, it will evolve from being able to solve one-time scenarios like plan-o-grams or truck loads, to large system-wide scenarios like store floor, regional distributions and eventually global supply chains.

Asset degradation modeling and utility system distribution optimization: Today, real-time data for operations is checked against rules, or against machine learning models, to identify issues that might compromise availability. With quantum computing, optimization of key systems could be an everpresent probabilistic recommendation for cost savings. Additionally, optimal product lifecycle and replacement could be determined at a system-wide scale to better understand the implications, and then broken down on a part-by-part basis.

Advertising scheduling and ad revenue maximization systems are often tailored on a per-customer basis. These systems collect hundreds of attributes about a consumer's preferences, which then need to be mapped to product affinities and represented as a graph. Ultimately, the decision on which ad to show a customer is an optimization of this graph, a task that a quantum computer is well-suited to tackle.

Portfolio risk optimization and fraud detection: Quantum computing shows promise in helping to determine attractive portfolios given thousands of assets with interconnecting dependencies. Additionally, quantum computing techniques could be used to more effectively identify key fraud indicators.

INDUSTRY	SAMPLE OPPORTUNITY AREAS FOR QUANTUM COMPUTING
Financial Services	**Portfolio risk optimization and fraud detection:** Quantur computing shows promise in helping to determine attract portfolios given thousands of assets with interconnecting dependencies. Additionally, quantum computing techniqu could be used to more effectively identify key fraud indica
Healthcare	**Protein folding and drug discovery:** Simulated annealing an algorithm currently used for the prediction of the effec of potential therapeutic approaches while optimizing for non-adverse effects. Quantum computing can replace so of these techniques, and may be able to show improveme at scale in the next few years such as advancing drug des to the point of providing personalized prescription drugs individual patients.
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